Particulate Inorganic Carbon from MODIS and VIIRS

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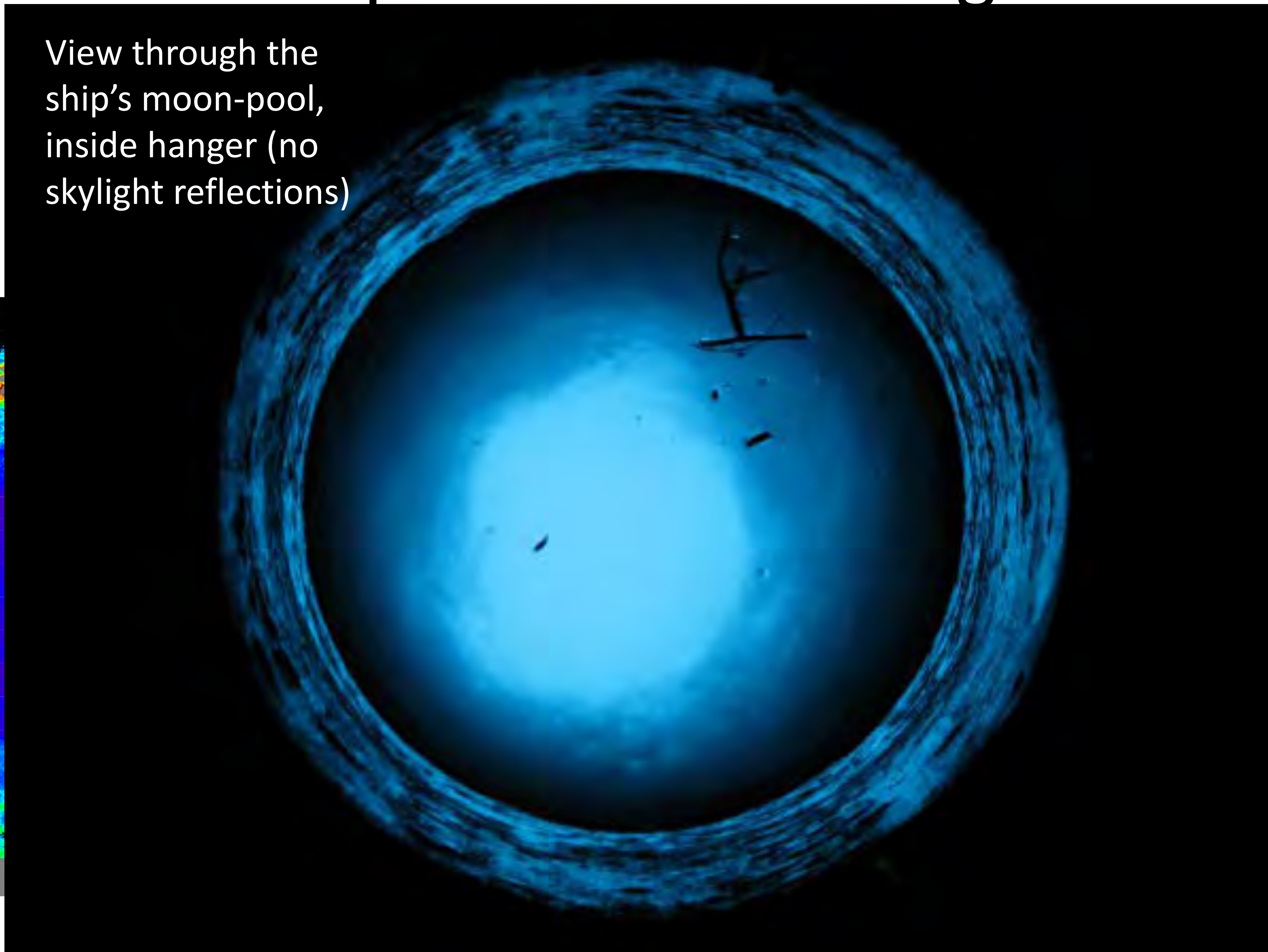
Coccolithophores are strong drivers of



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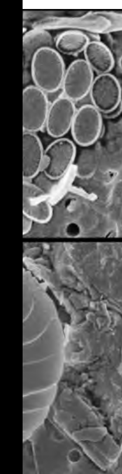


toporous

Great Calcite Belt

Activities since I presented last…

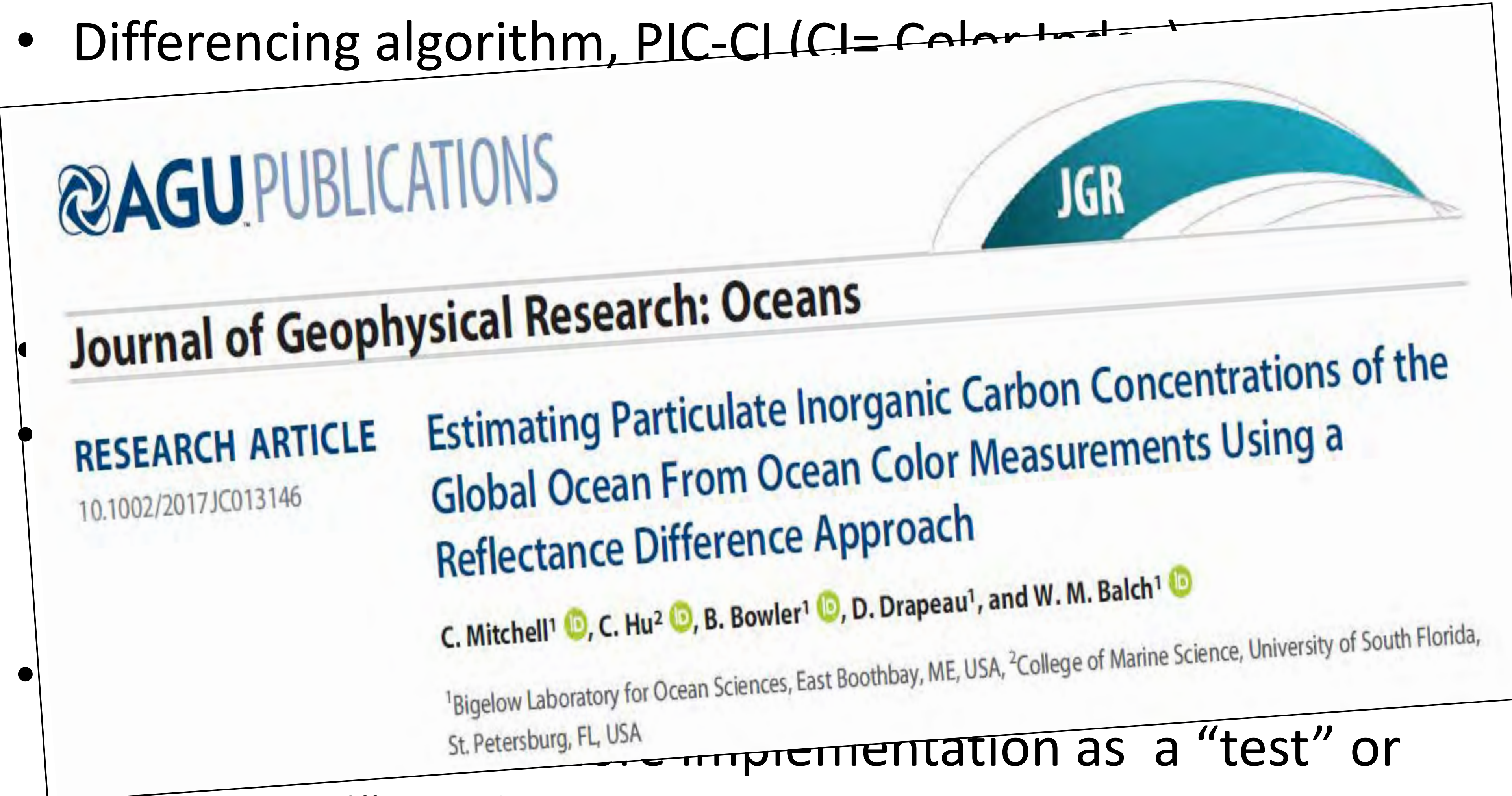
- Algorithm work
- Validation activities
- New insights/publications

Algorithm news

- Algorithm maintenance- Continued updating look-up table for PIC algorithm with new shipboard values for PIC, acidified backscattering vs chlorophyll relationship
- Algorithm applied to both MODIS and VIIRS imagery (not exact wavelength match).
- Algorithm revisions (Calcite.c) passed to the Ocean SIPS (Bryan Franz) for reprocessings
- New PIC algorithm- Color index algorithm

New PIC algorithm Published

- Differencing algorithm, PIC-CI (CI= Color Index)



AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE

10.1002/2017JC013146

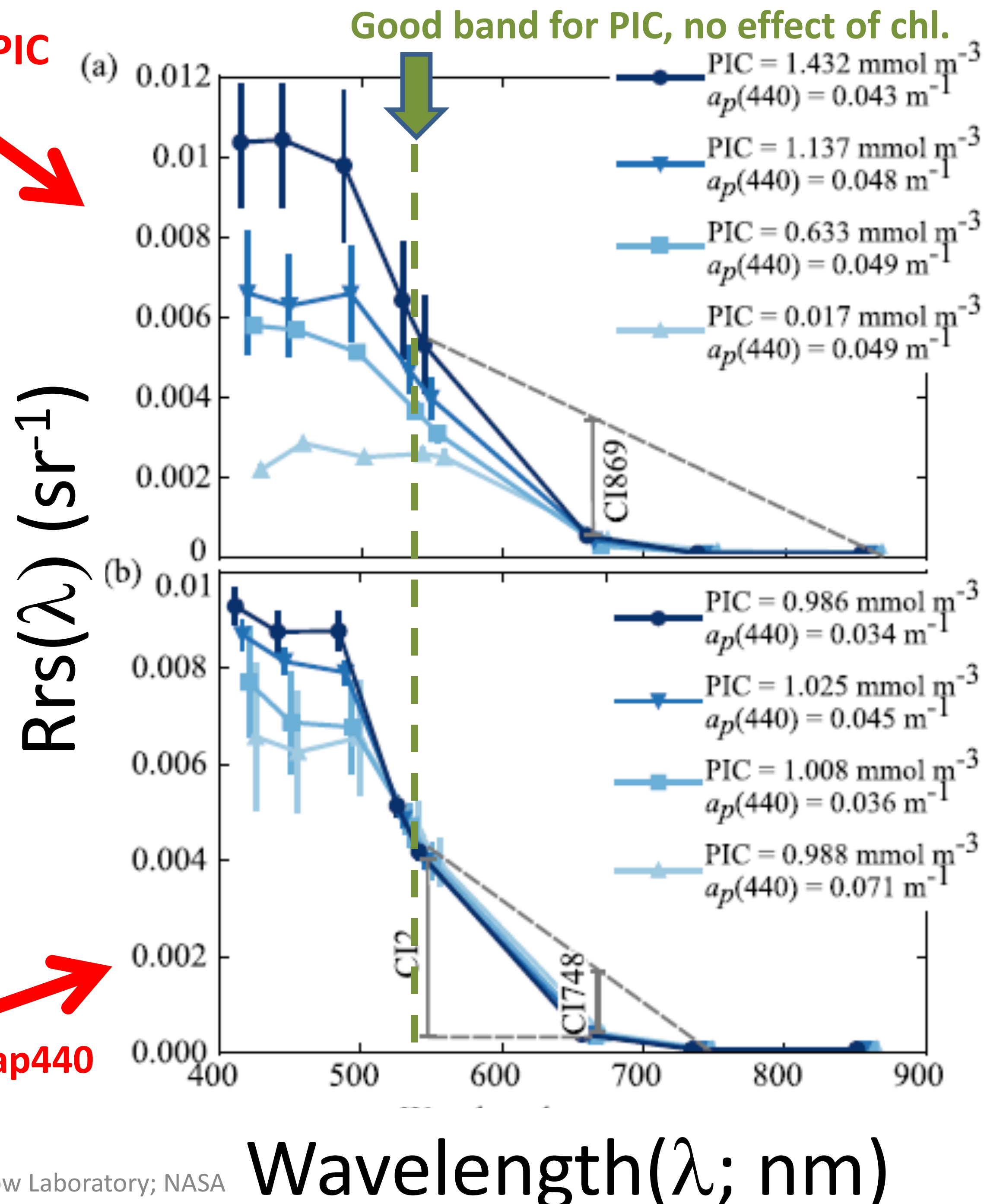
Estimating Particulate Inorganic Carbon Concentrations of the Global Ocean From Ocean Color Measurements Using a Reflectance Difference Approach

C. Mitchell[1], C. Hu[2], B. Bowler[1], D. Drapeau[1], and W. M. Balch[1]

[1]Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA, [2]College of Marine Science, University of South Florida, St. Petersburg, FL, USA

implementation as a "test" or "provisional" product.

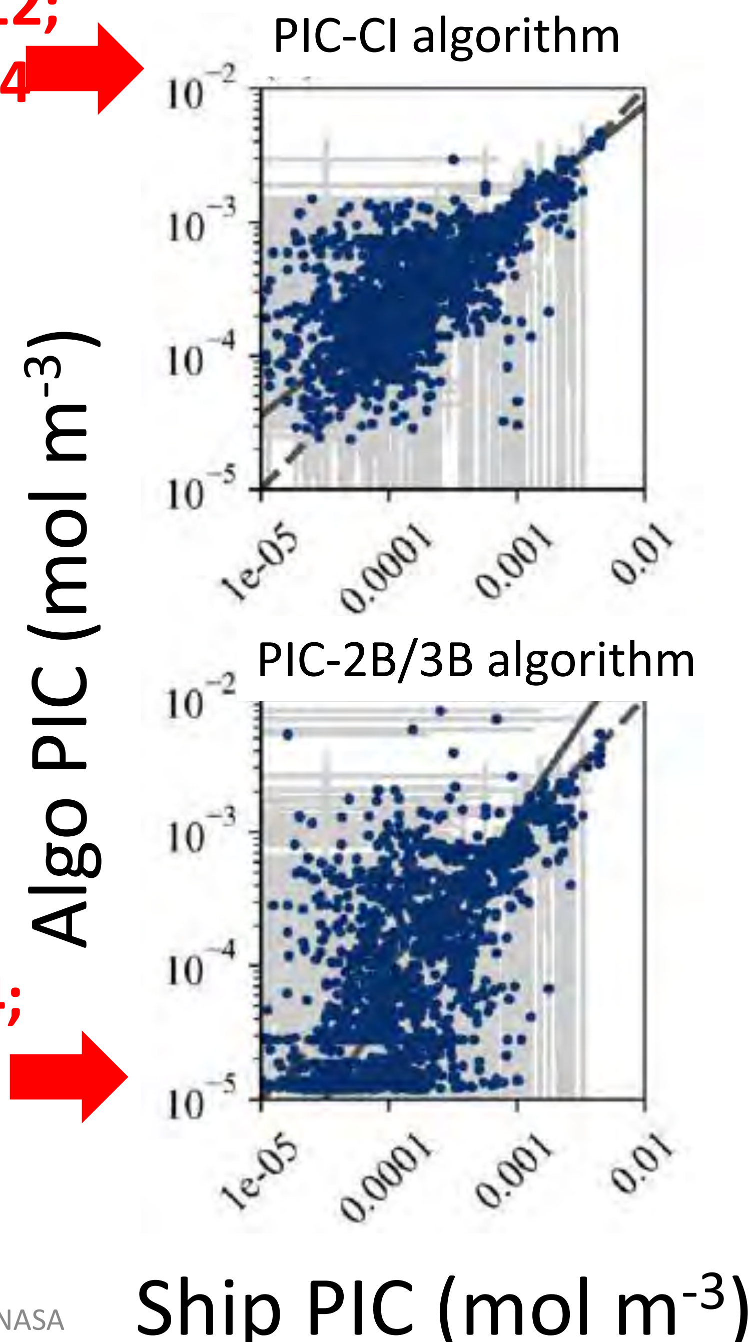
Principle of the CI approach…



R^2 = 0.51; RMSE=0.12; mean abs. diff = 0.34 log units

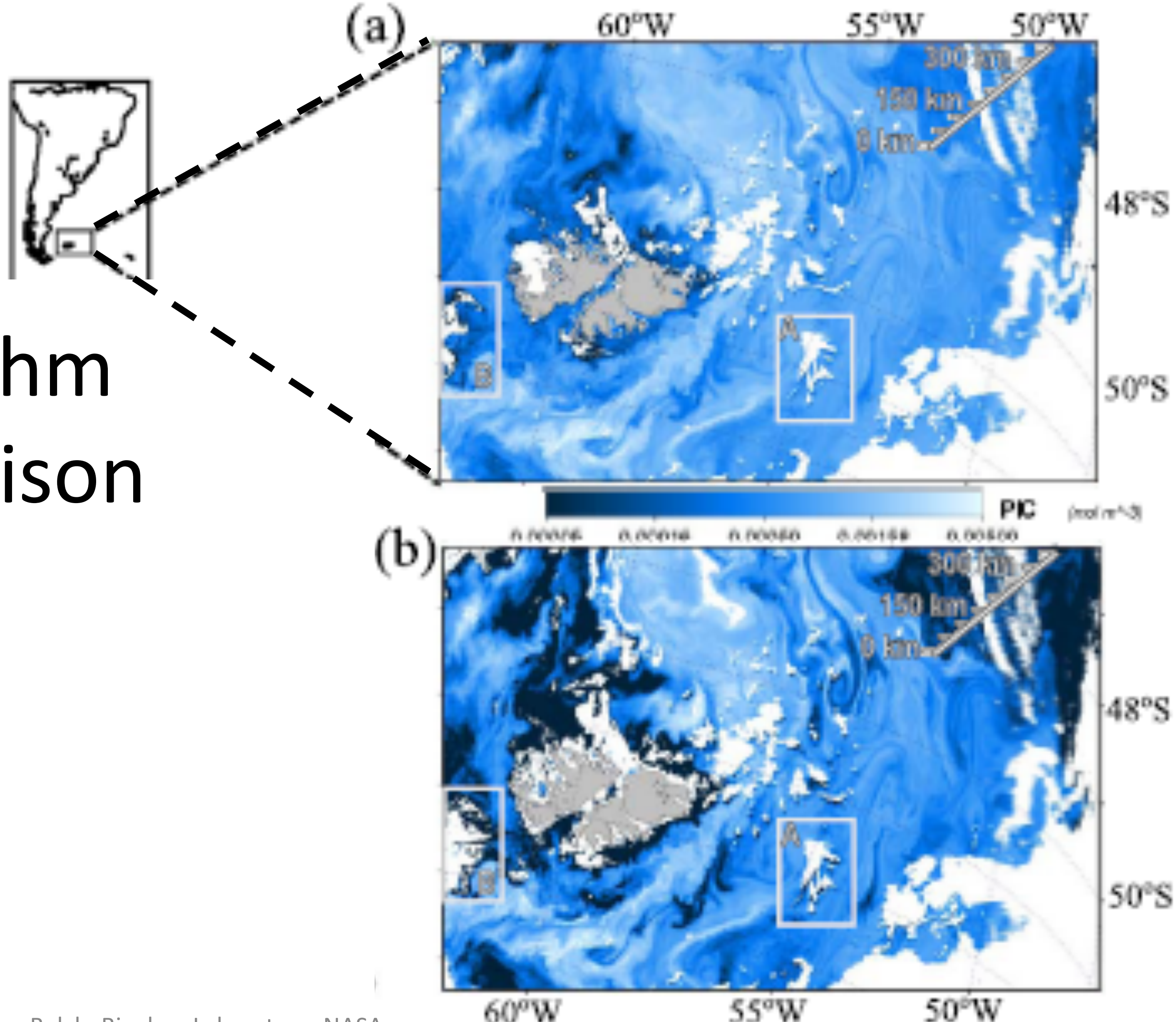
The new PIC-CI algorithm shows improved r^2 and reduced RMSE over current algorithm

R^2 = 0.32; RMSE= 0.14; mean abs diff =0.43 log units



Algorithm comparison

PIC- 2B/3B



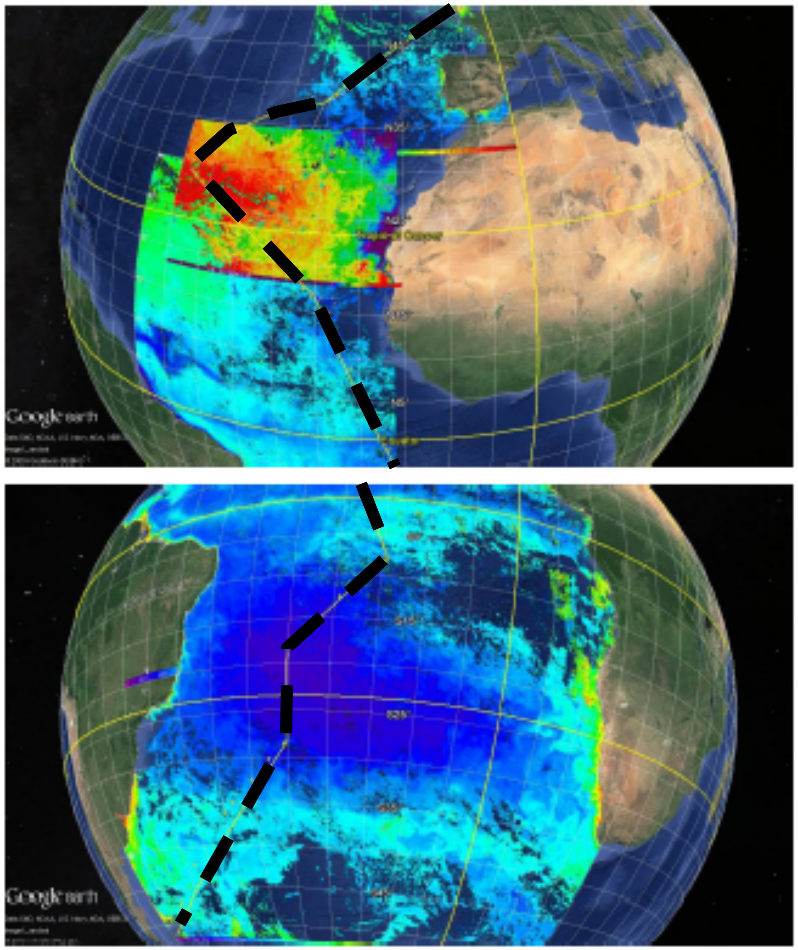
PIC- CI

Validation activities

Atlantic Meridional Transect Cruises

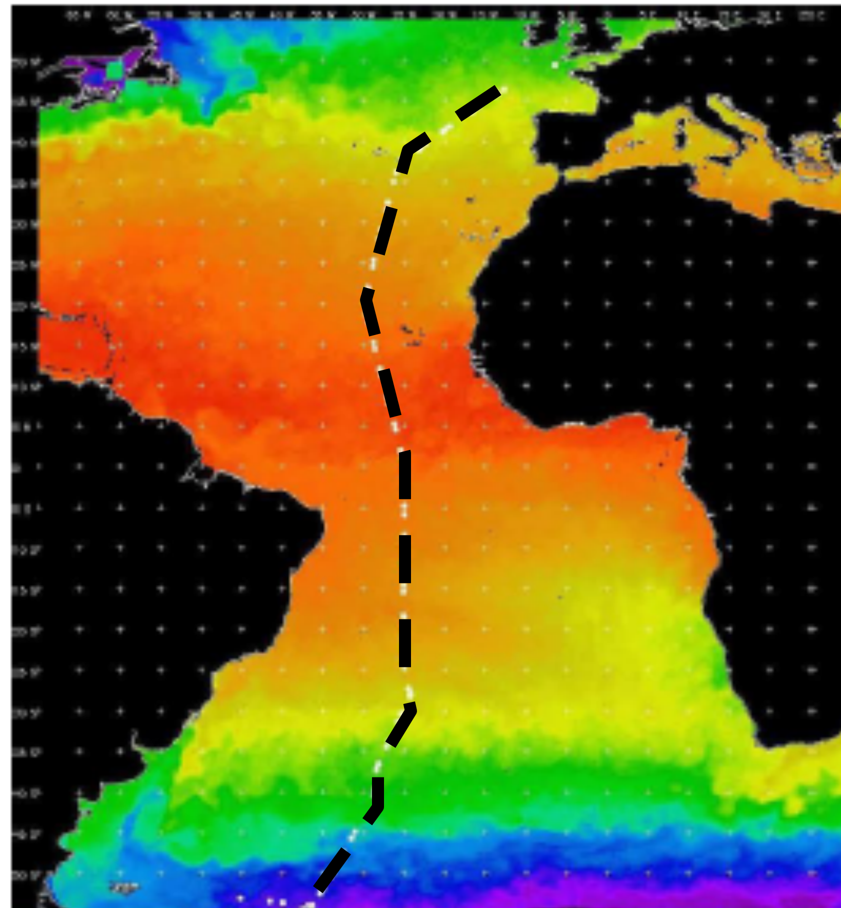
- We completed and processed AMT cruises 25 and 26; providing PIC, coccolithophore enumeration and coccolithophore SEM's; above-water radiometry; inherent optical properties (spectral absorption, attenuation, backscattering)
- Paper in revision (Global Biogeochemical Cycles) summarizing our AMT cruise work

AMT Cruise Tracks #25 & #26



AMT25 cruise track overlaid by NEODAAS satellite products provided during the expedition. From top to bottom: VIIRS chlorophyll, AVHRR SST, VIIRS Euphotic depth and VIIRS chlorophyll.

AMT 25



AMT 26

R/V Endeavor

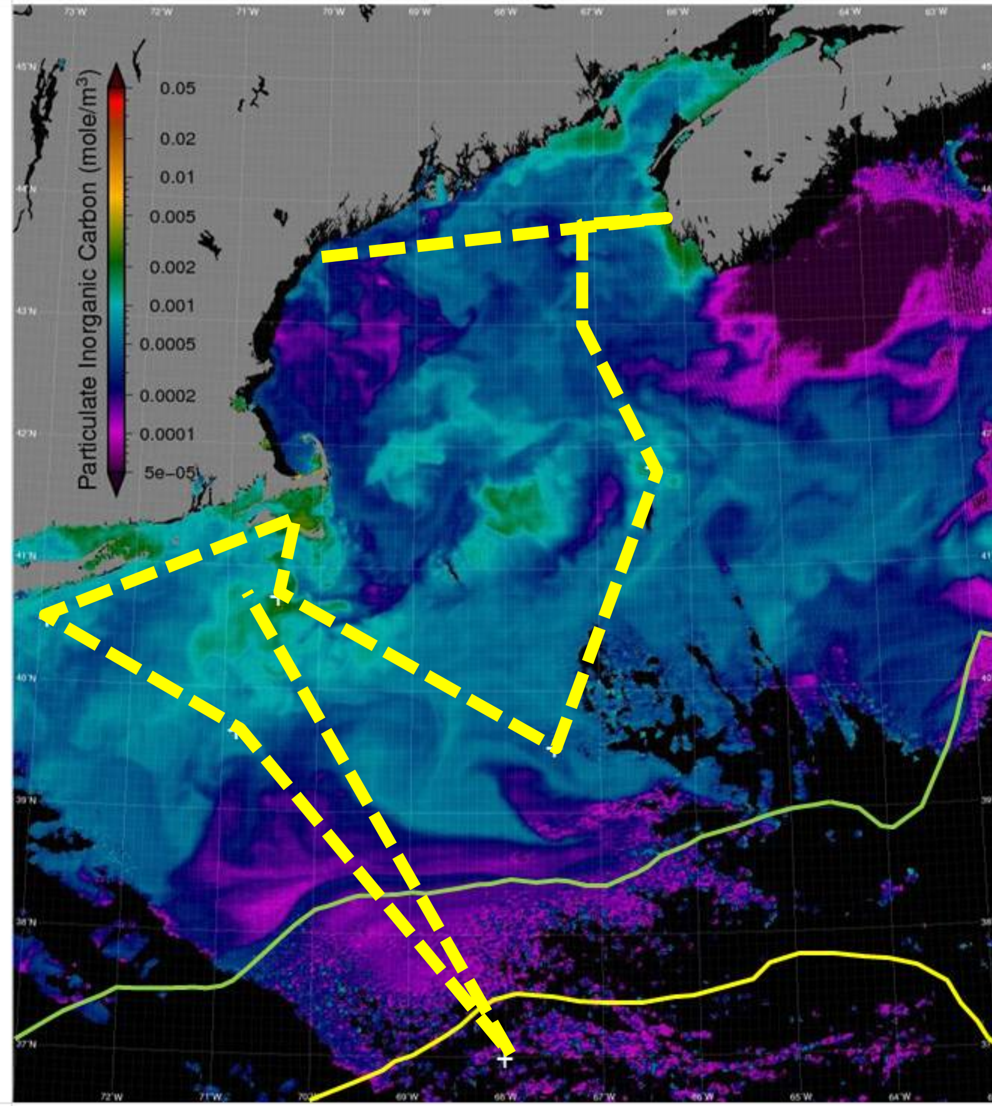
July 2018

NSF-funded cruise

Ran GNATS line

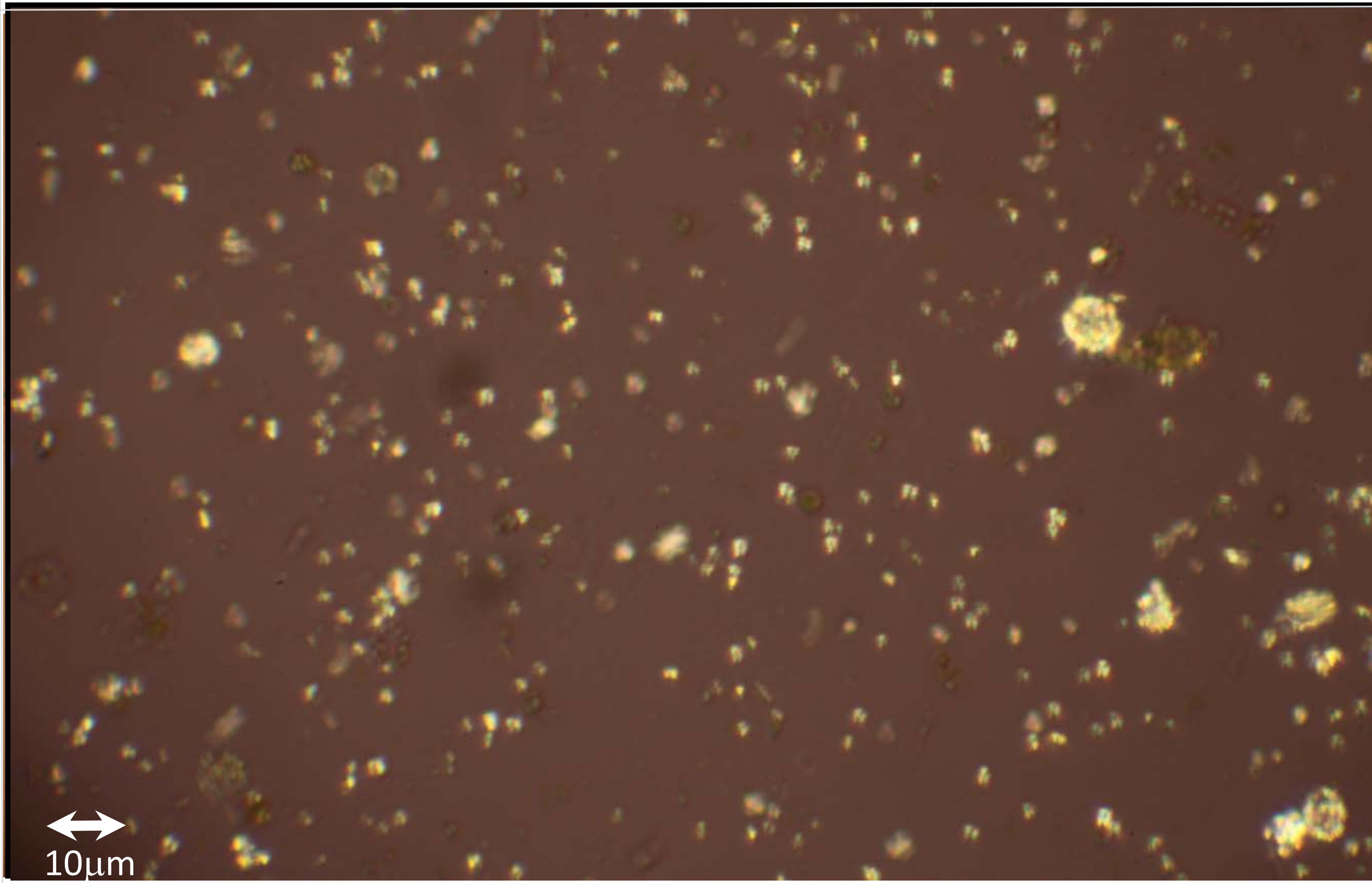
Largest cocco bloom (in area) in NE Continental Shelf in 30y!

MODIS Aqua; PIC-CI algorithm



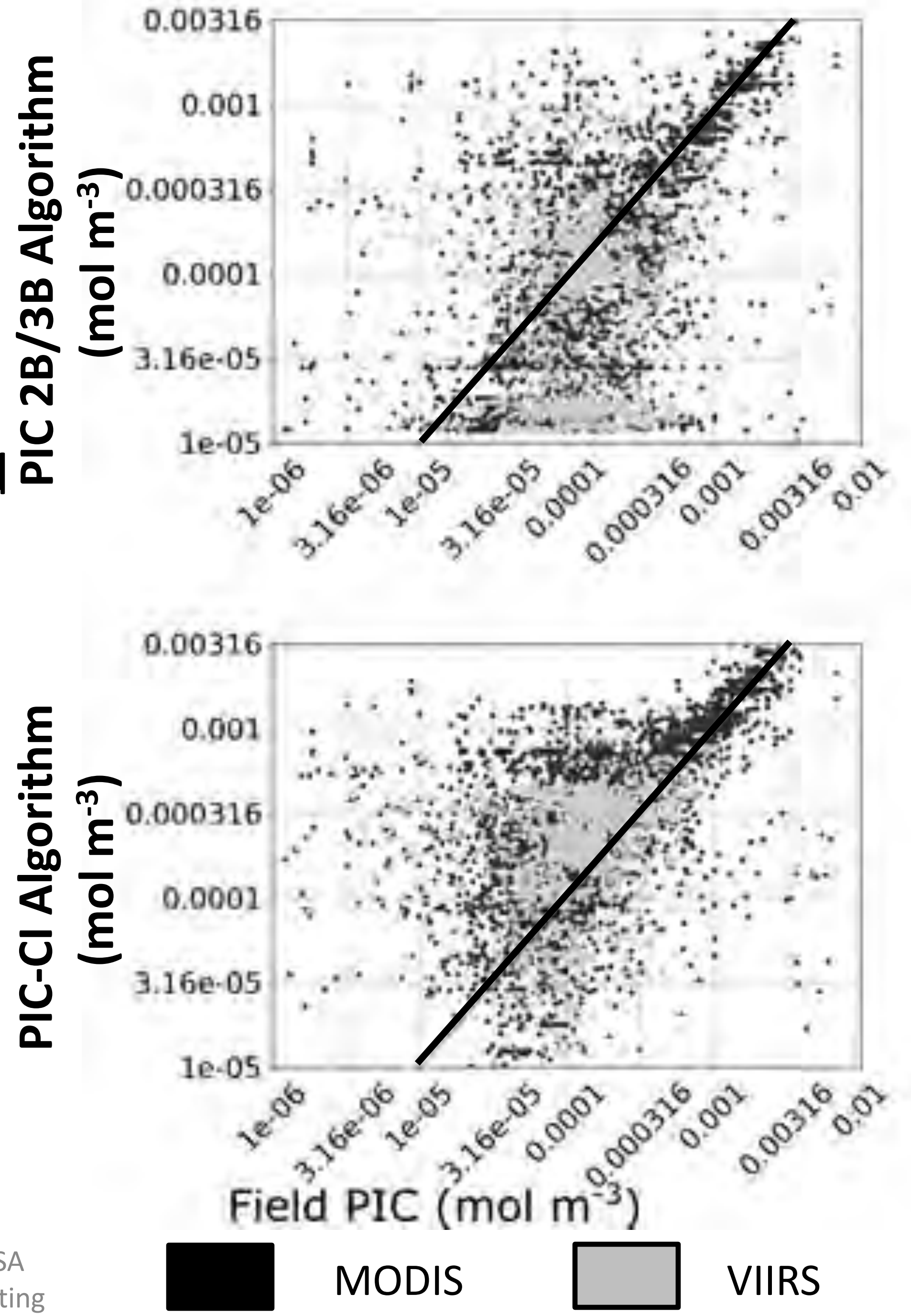
R/V Endeavor 616

Coccolithophore bloom: What was in the water?

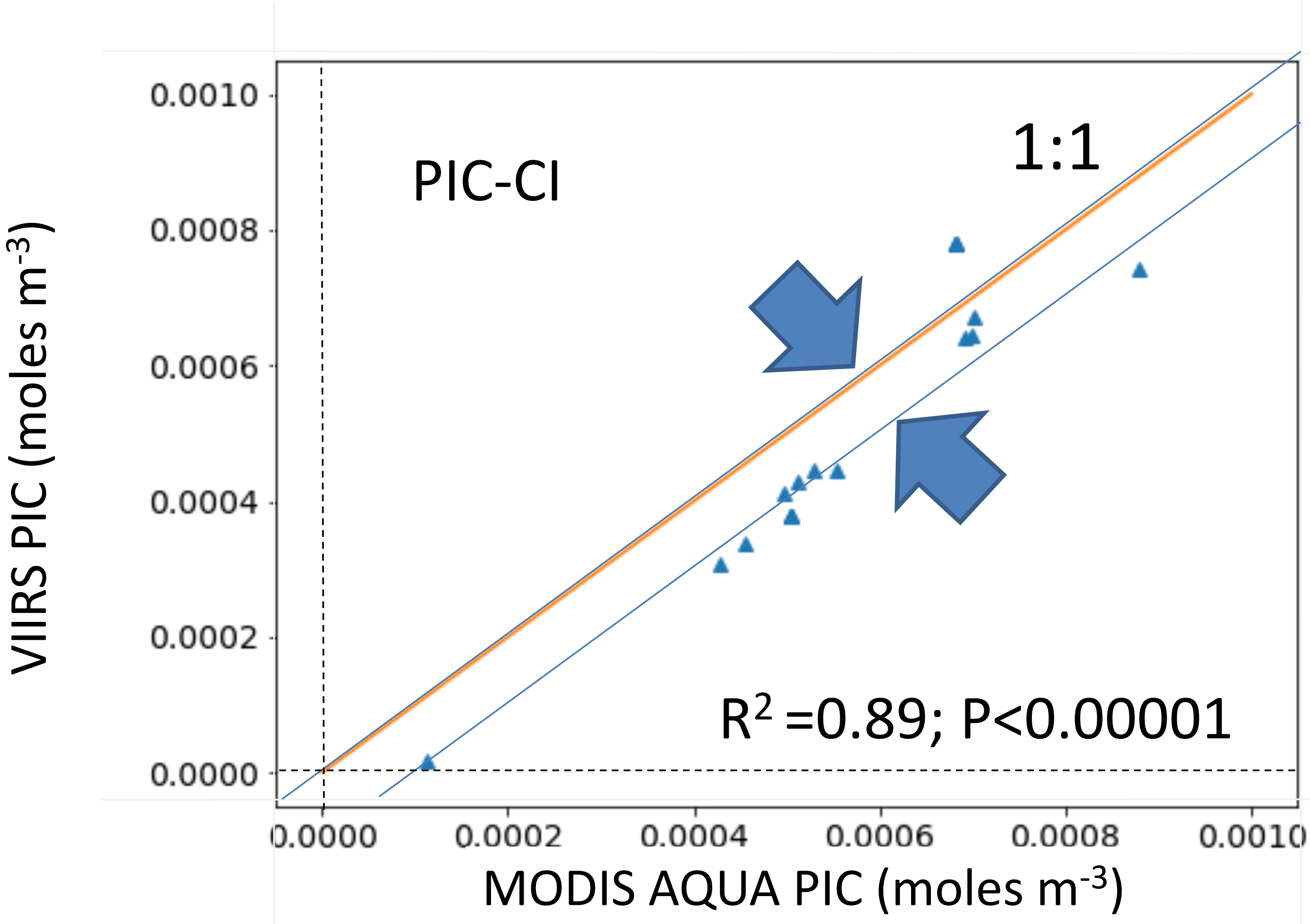


New validation data-

- 3 years ago- 74 validated stations with ICPOES
- Now 374 absolutely validated stations with ICPOES
- VIIRS data distributions show continuity with MODIS
- Relative error for VIIRS distribution nonetheless greater than for MODIS (because highest PIC concentration validated by VIIRS was still 10X lower than for MODIS



Sensor intercomparison validation stations for two AMT cruises and one GCB cruise



New Insights

- 1) Great Calcite Belt; new focus on the GCB and Sub-Antarctic Mode Water

Publication on Great Calcite Belt…

AGU PUBLICATIONS

Global Biogeochemical Cycles

RESEARCH ARTICLE
10.1002/2016GB005414

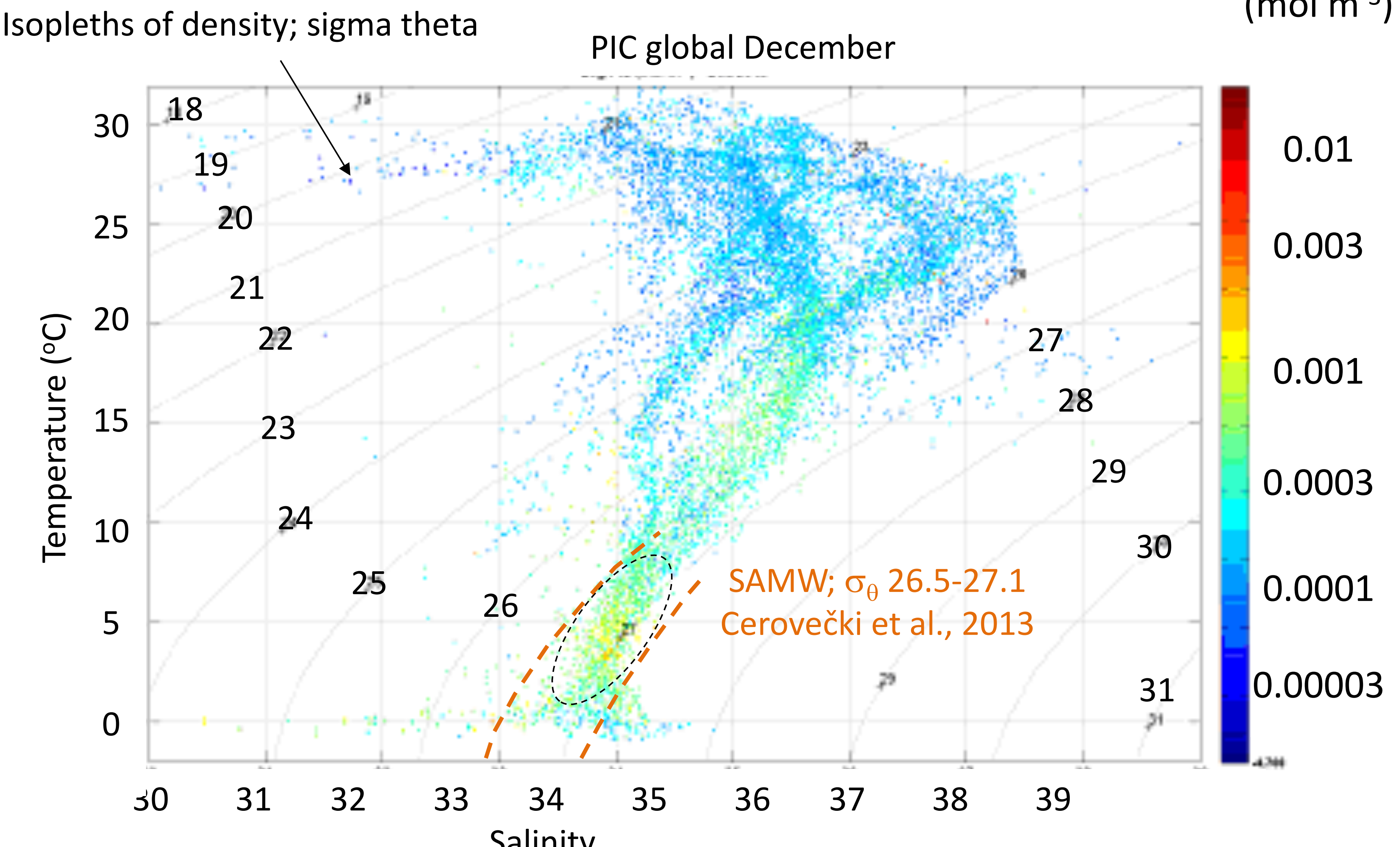
Factors regulating the Great Calcite Belt in the Southern Ocean and its biogeochemical significance

William M. Balch[1], Nicholas R. Bates[2,3], Phoebe J. Lam[4,5], Benjamin S. Twining[1], Sarah Z. Rosengard[4,6], Bruce C. Bowler[1], Dave T. Drapeau[1], Rebecca Garley[2], Laura C. Lubelczyk[1], Catherine Mitchell[1], and Sara Rauschenberg[1]

Demonstrate for the GCB:

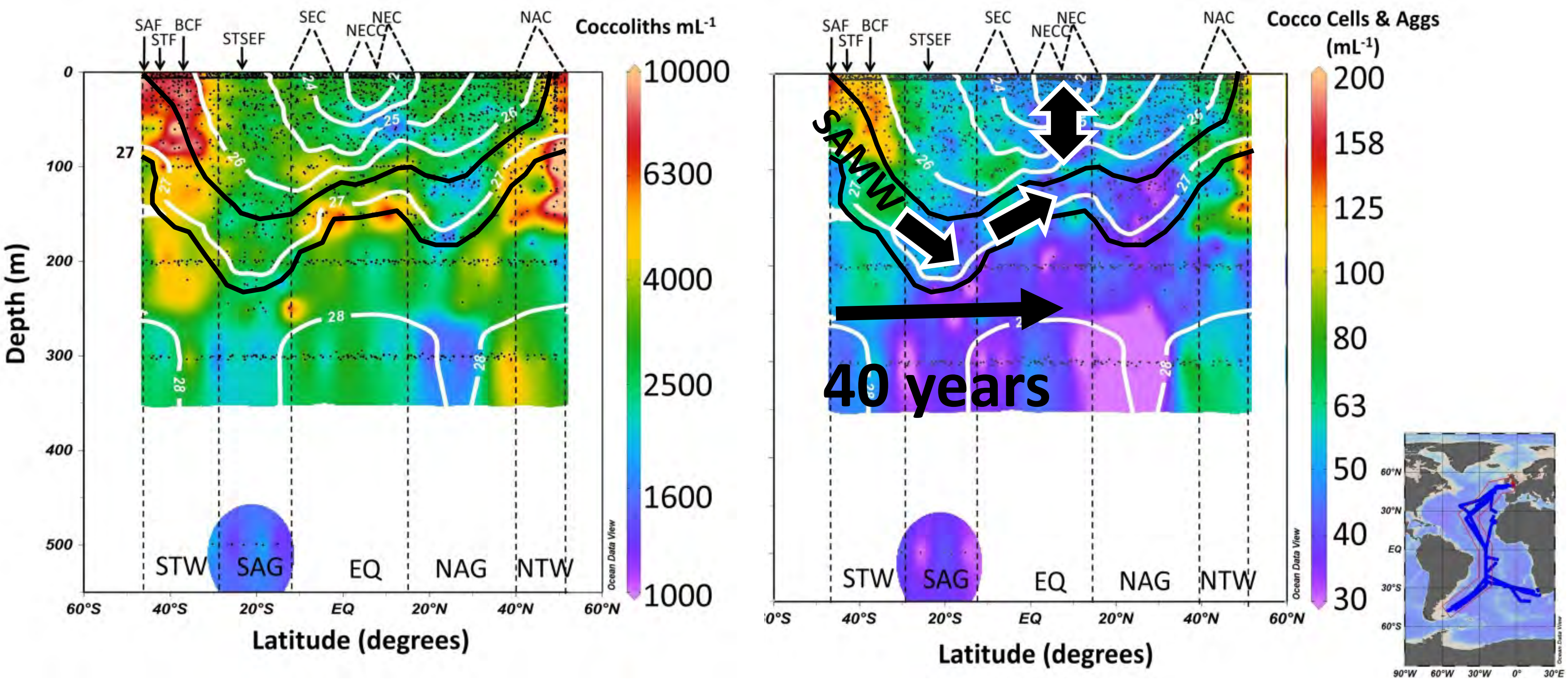
- Its appearance in high-velocity waters of the Antarctic Circumpolar Currrent
- Macronutrient requirements for growth (nitrate, silicate)
- Trace element requirements (iron, zinc)
- Consequences for efficiency of carbon export

Plot surface PIC concentration in temperature/salinity space



Balch, Bigelow Laboratory; NASA

Atlantic coccolithophores carried North from Great Calcite Belt in SAMW



****NOTE*** Low surface concentrations at Equator!

New Pub: Algorithm to convert surface PIC to integral euphotic PIC (Balch et al., 2018)

AGU PUBLICATIONS

Global Biogeochemical Cycles

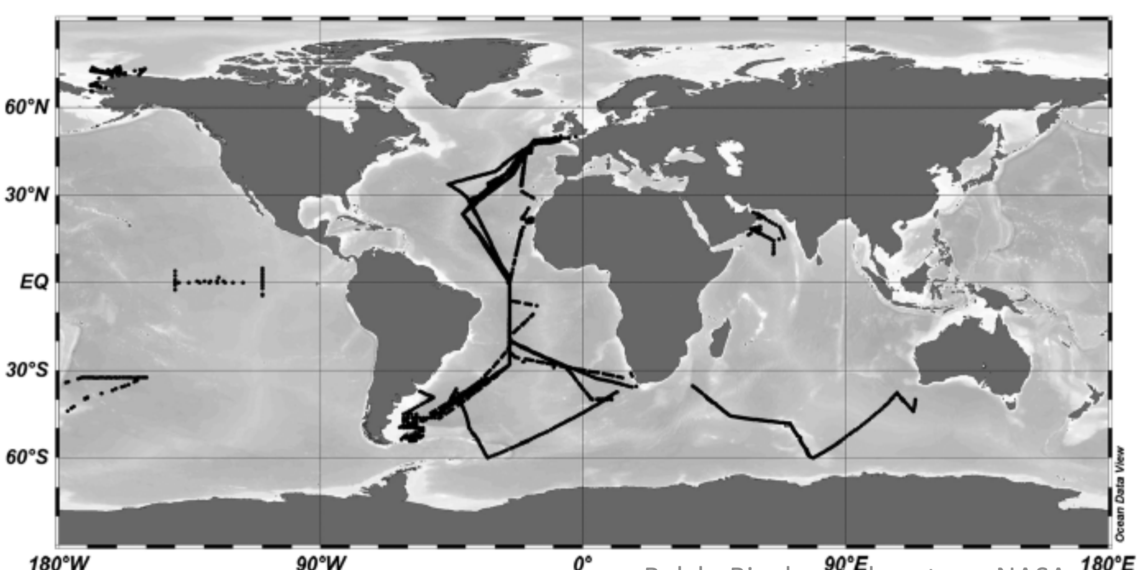
RESEARCH ARTICLE
10.1002/2016GB005614

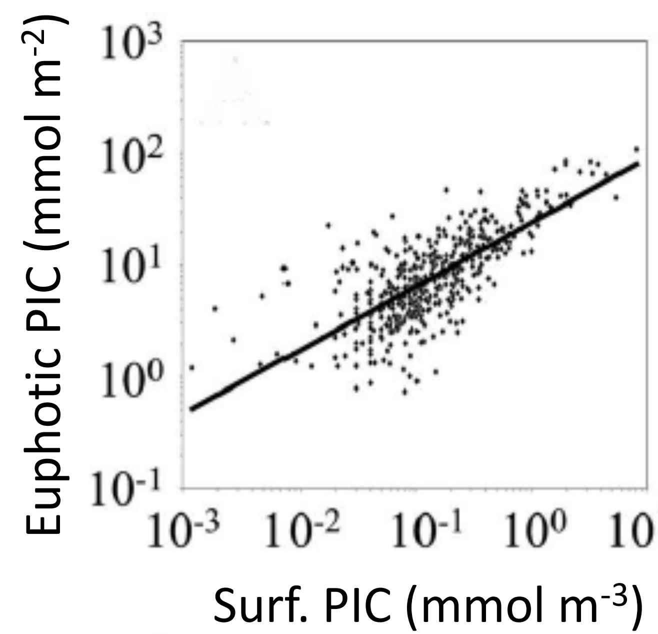
2018

Vertical Distributions of Coccolithophores, PIC, POC, Biogenic Silica, and Chlorophyll *a* Throughout the Global Ocean

William M. Balch[1], Bruce C. Bowler[1], David T. Drapeau[1], Laura C. Lubelczyk[1], and Emily Lyczkowski[1]

[1]Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA





New pub: Algorithm for coccolithophore calcification (Hopkins & Balch, 2018)

AGU100 ADVANCING EARTH AND SPACE SCIENCE

JGR

Journal of Geophysical Research: Biogeosciences

RESEARCH ARTICLE
10.1002/2017JG004235

A New Approach to Estimating Coccolithophore Calcification Rates From Space

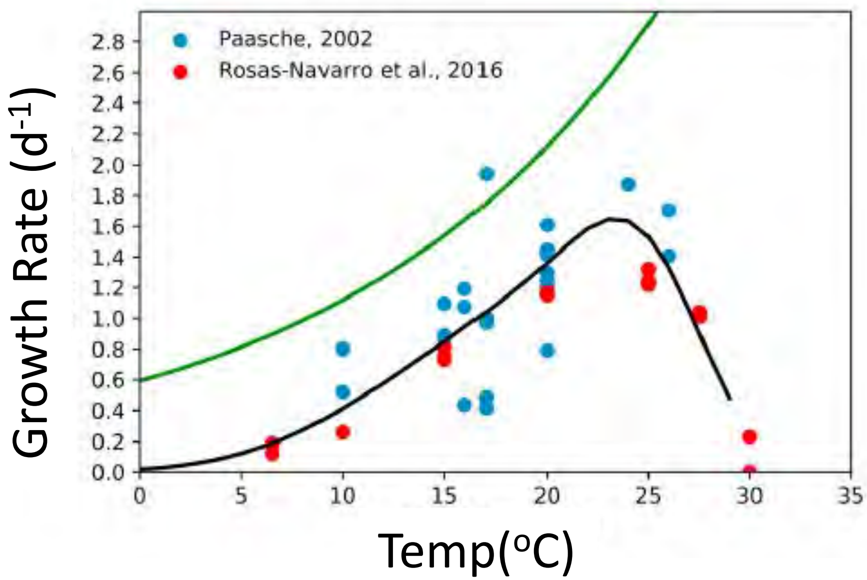
Jason Hopkins[1] and William M. Balch[1]

[1]Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA

2018

- **Based on Behrenfeld carbon based productivity model (Behrenfeld et al., 2005)**
- **PIC production = f [PIC; μ] h(I_0); g(Z_{eu})**
- **Assumes: μ is a function of temperature and irradiance**

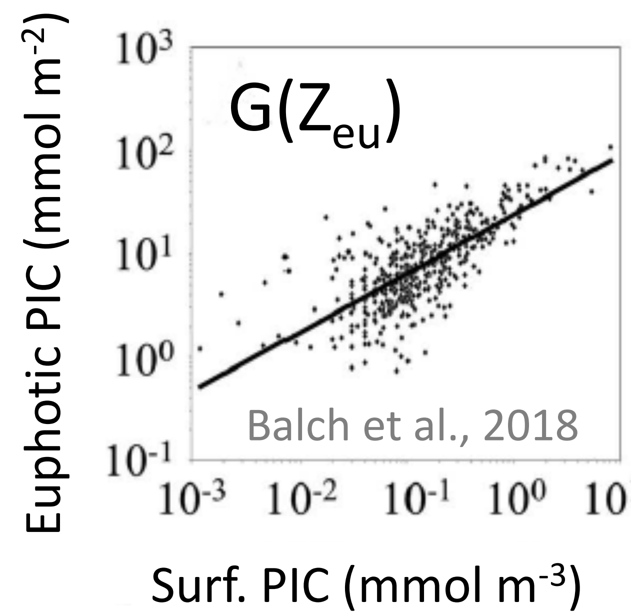
Components of Hopkins and Balch (2018) calcification algorithm



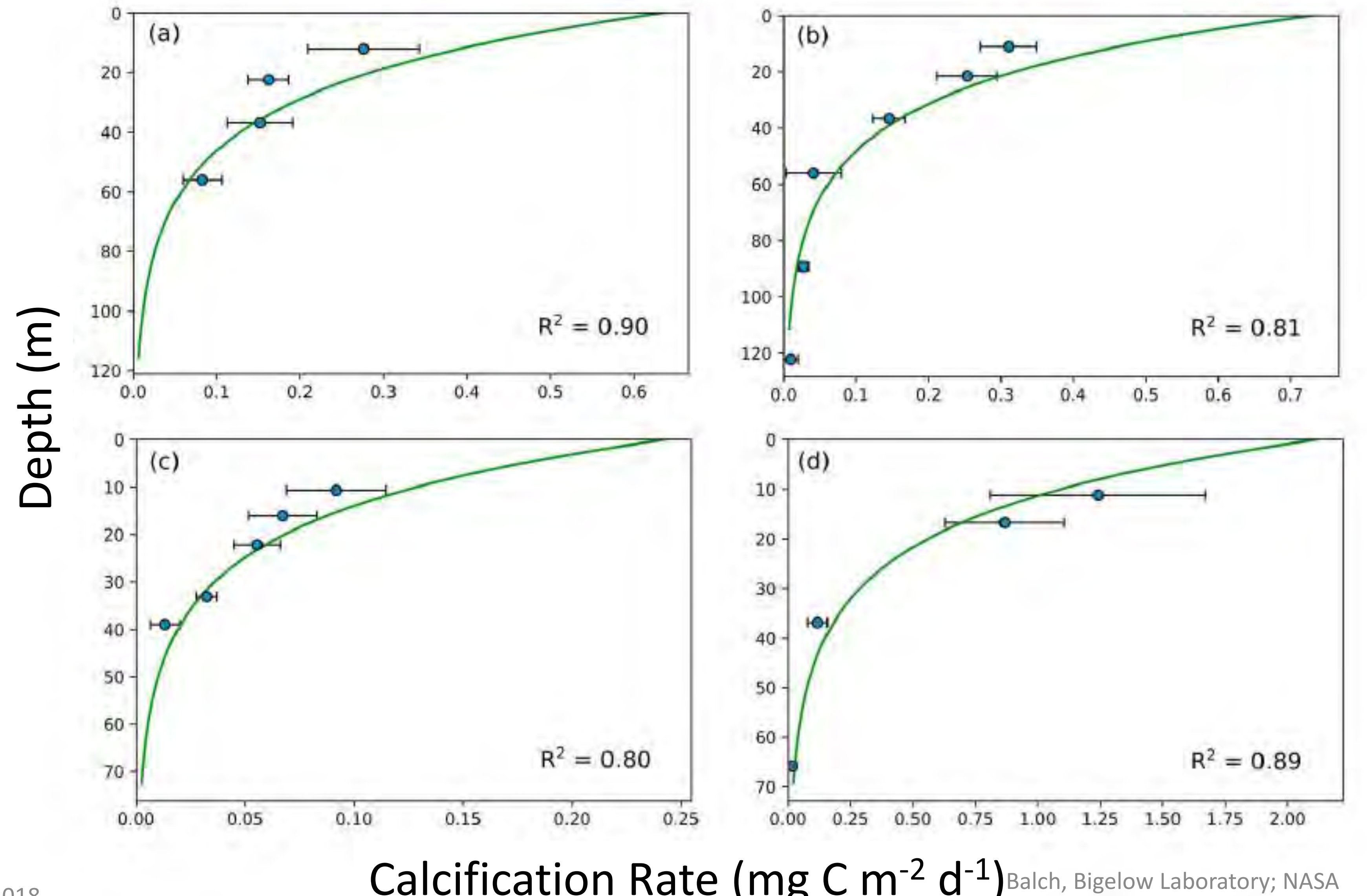
$$h(I_0) = \left(1 - e^{\left[\frac{-E}{K_E}\right]}\right)$$

$$\mu_{T_{corr}} = \begin{cases} \log(2)0.35\left(1.09^{T}\right)\ e^{-|T-T^{opt}|^{3}/T^{low}_{scale}} & T \leq T^{opt} \\ \log(2)0.35\left(1.09^{T}\right)\ e^{-|T-T^{opt}|^{3}/T^{high}_{scale}} & T > T^{opt} \end{cases}$$

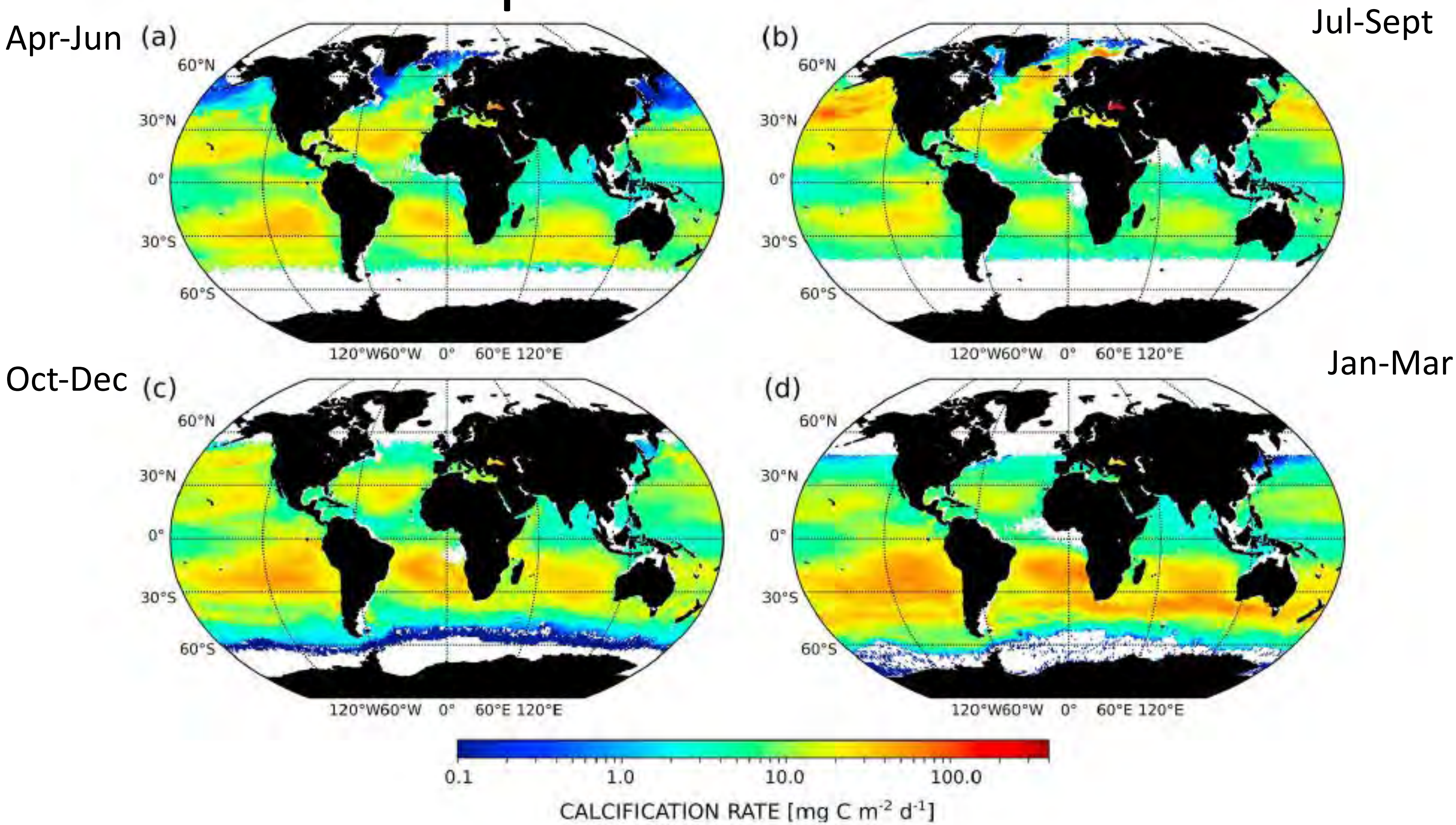
Where T^{opt} =20°C; $T^{low}{}_{scale}$=2°C; $T^{high}{}_{scale}$=~24°C



Performance of Hopkins & Balch (2018) calcification algorithm

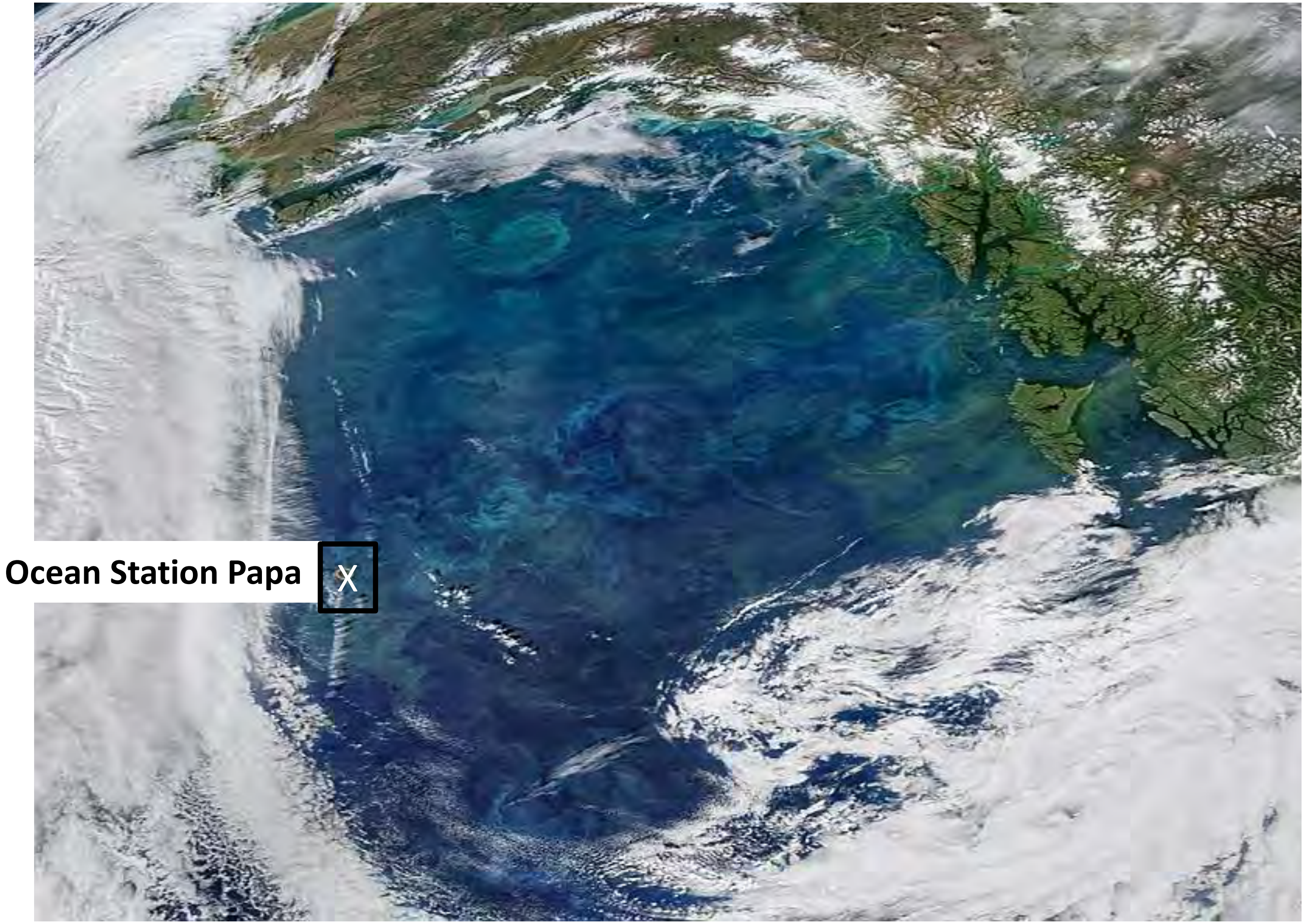


New global predictions of integrated euphotic calcification



Average, global, euphotic zone depth-integrated calcification rate is estimated to be 1.42 ± 1.69 Pg particulate inorganic carbon/year with the oceanic gyres contributing the greatest influence.

VIIRS: 30 September, 2018; True Color

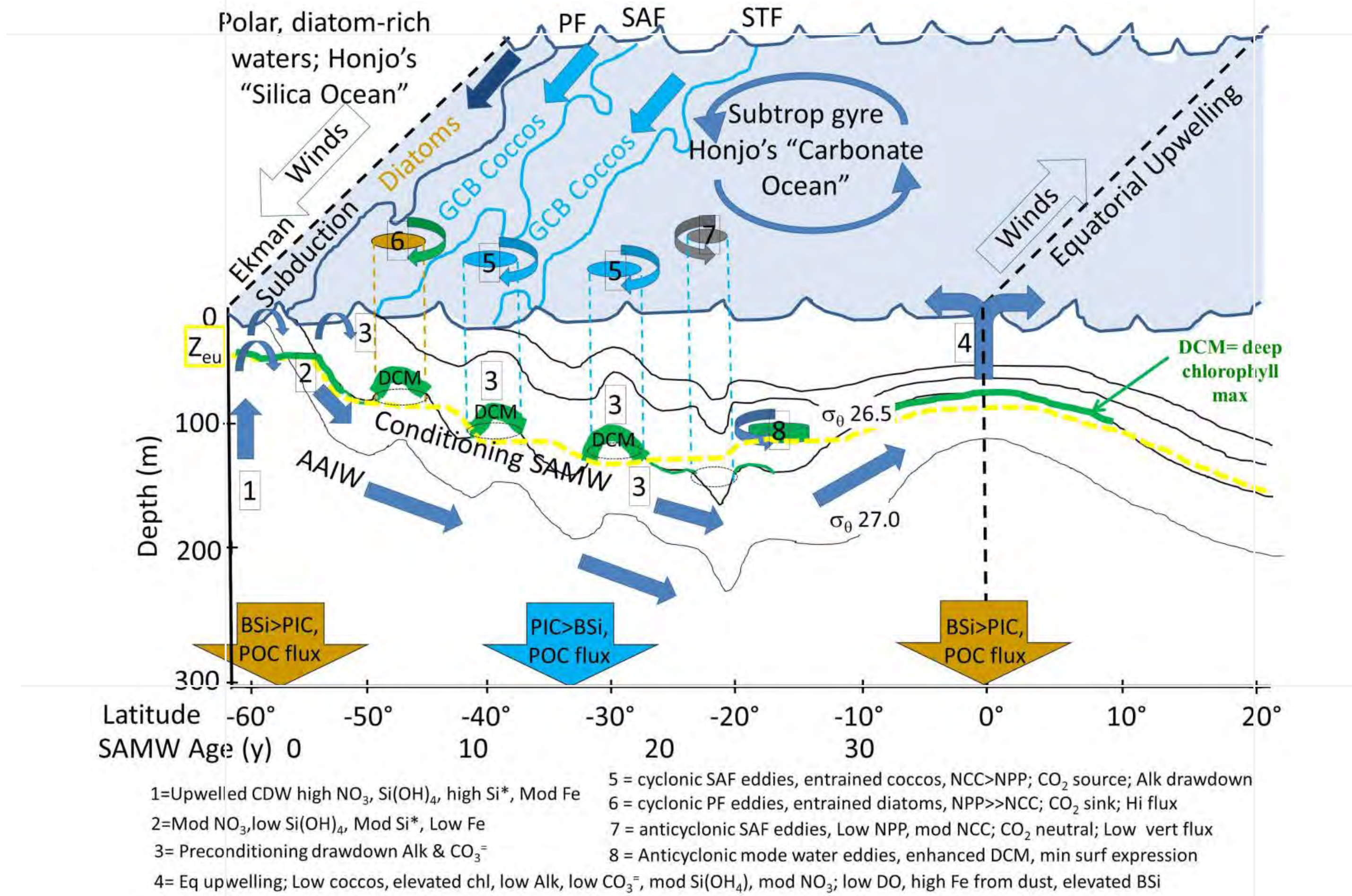


Site of EXPORTS first field study: Note turquoise coccolithophore populations at SubArctic Front

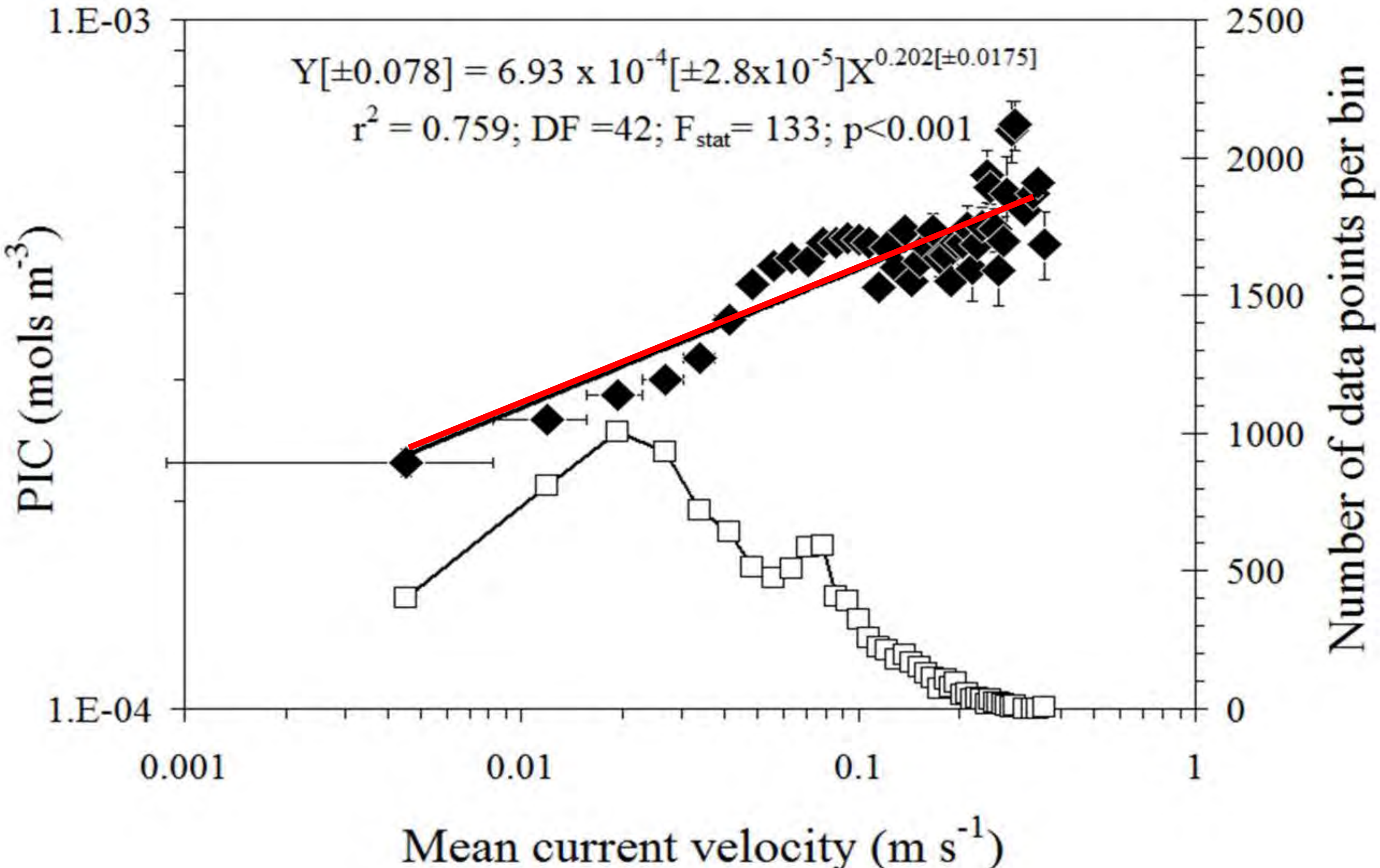
Summary

- Continued algorithm maintenance of 2B/3B merged algorithm
- Validation Activities AMT cruises and NW Atlantic: quadrupled in situ data on PIC
- New publications from the Balch group at Bigelow Laboratory:
  - New PIC-CI algorithm (Mitchell et al., 2016)
  - Factors affecting the Great Calcite Belt (Balch et al., 2016)
  - Relating surface PIC to euphotic PIC (Balch et al., 2018)
  - New algorithm for estimating global calcification (Hopkins and Balch, 2018)
- *Thank you!*

Conceptual View of Subantarctic mode water export… "So what?"

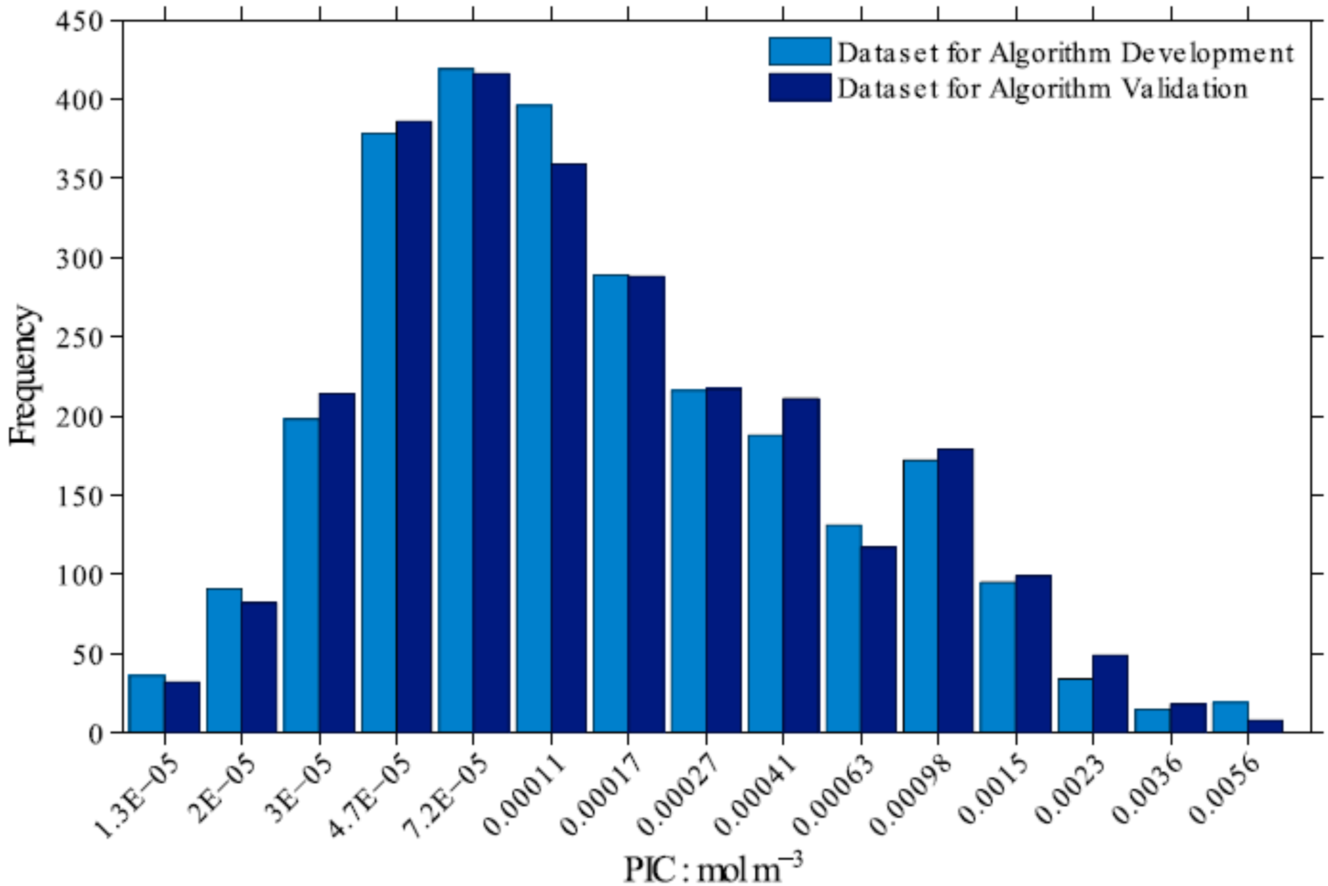


Great Calcite Belt sits in high-velocity circumpolar currents of the Southern Ocean…likely sites of high Ekman pumping

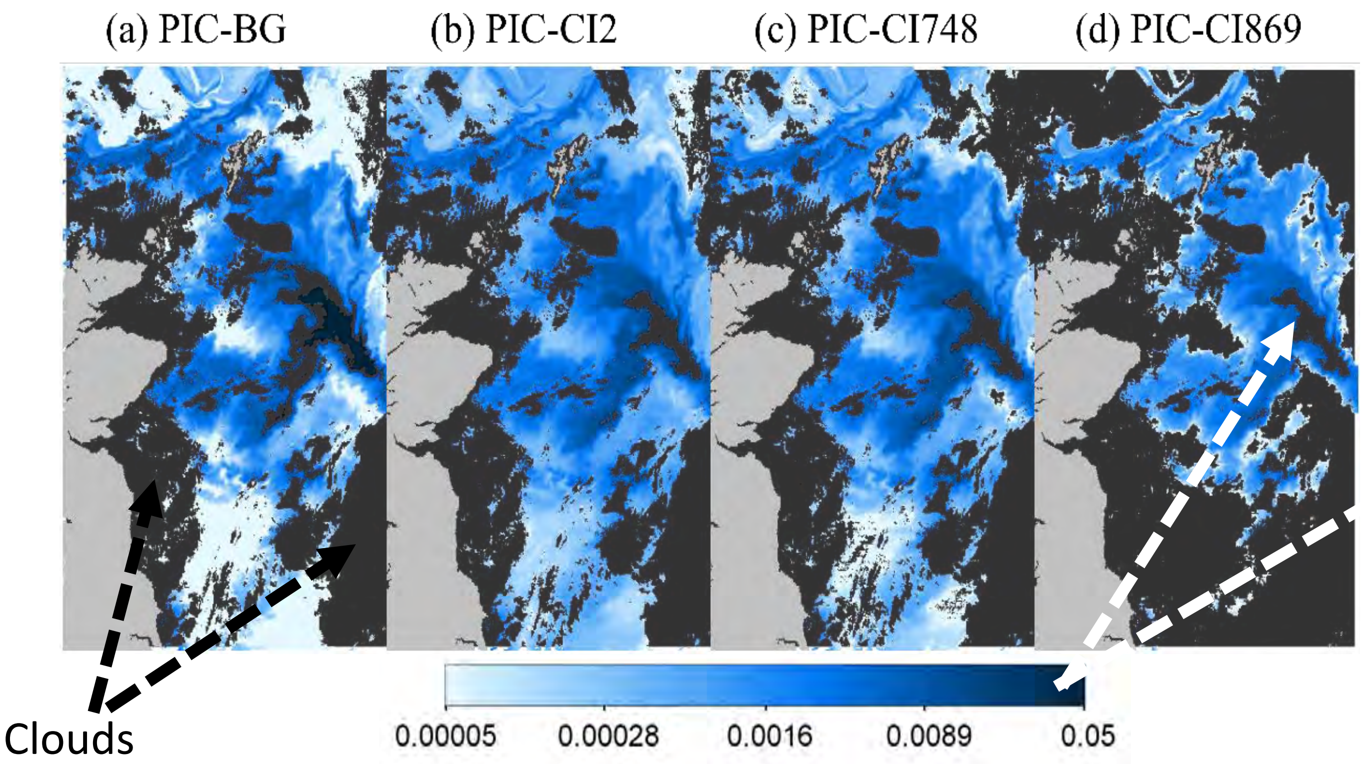


Balch et al., 2016; GBC

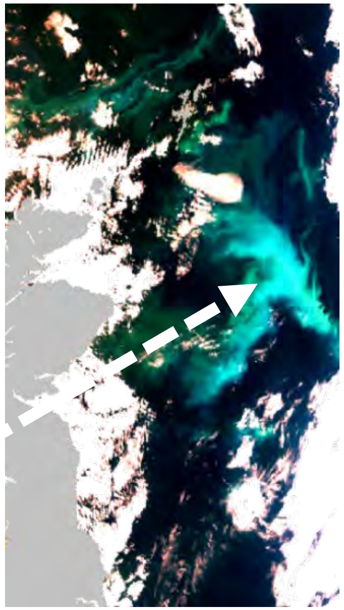
Divided our PIC data into two bins Algorithm development & validation



More comparisons…



PIC concentration in the North Sea, 5th June 2003.



Quasi-true color image of the North Sea on 5th June 2003

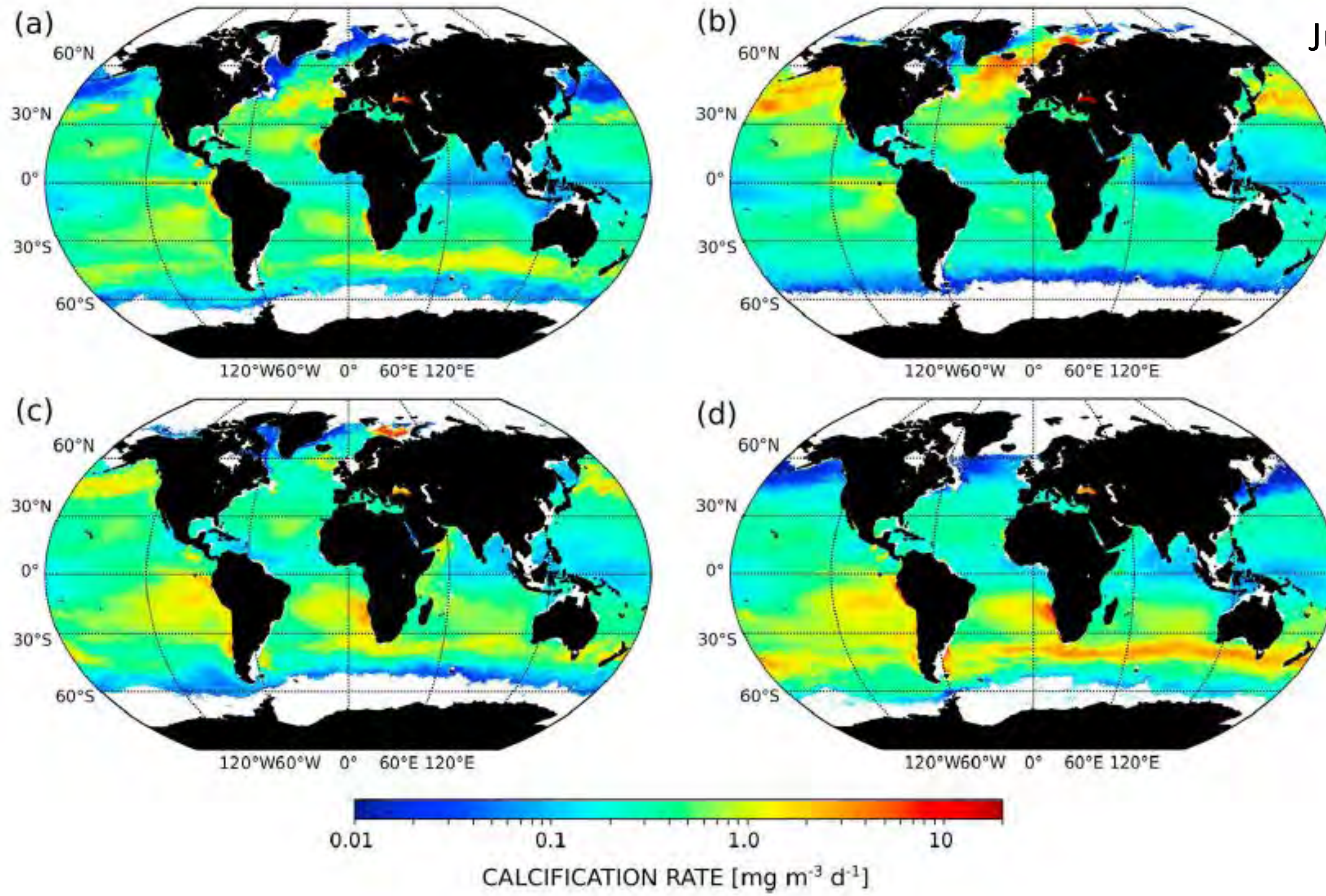
New global predictions of surface calcification

Apr-Jun

Jul-Sept

Oct-Dec

Jan-Mar



Calcification rates are generally highest in the Pacific subarctic and N. Atlantic in N. hemisphere summer and in the Great Calcite Belt and W. African upwelling in S. Hemisphere summer.